R68-2

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A Comparison of Solvent and Thermal Techniques for Determining the Fat Content of Ground Beef

SUMMARY—Results obtained by a thermal extraction procedure for determining the fat content of fresh ground beef were found to correlate significantly (1% level) with results obtained by the official AOAC solvent extraction procedure. The fat levels investigated ranged between 14 and 29%. As the amount of sample grinding increased, the fat variation within thermal extraction replications decreased, while the differences between the thermal and solvent extracted fat became larger.

Linear regression between the two methods contained significant error in certain areas of the fat range tested. The fourth order polynomial provided the best fit curve between the solvent and thermal extraction data for thermal samples ground once through a plate having ¾-in. diameter holes and twice through a plate having holes ⅛-in. in diameter. The thermal extraction method, being adequately reproducible, rapid, and economical, provides a valuable tool to the food industry in control procedure and to the Armed Forces in its quality assurance tests.

INTRODUCTION

A REPRODUCIBLE, RAPID, AND ECONOMICAL METHOD for determining the fat content of various foods, after production, or within the time limit when suitable adjustments could be easily made, is urgently needed in a broad segment of the food industry. For related reasons, such a method is also urgently needed by the Armed Forces as a major step toward a more practical and effective program for quality assurance.

Oesting *et al.* (1945) described one of the earlier methods of rapid fat analysis for controlling the manufacture of meat and meat products. Kelley *et al.* (1953) compared the AOAC method with four rapid solvent extraction techniques. Results showed that the AOAC and modified Babcock method, using sulphuric acid, gave comparable results; however, the accuracy of the modified Babcock method was reduced by the occurrence of meat spices and its limited sample size.

With the advent of instrumentation for fat analyses, Furgal (1954) investigated the comparability between the AOAC method and the Steinlite LOS Fat Tester. The two methods were found to be comparable and the latter possessed the advantage of a 50 g sample requiring a time of 20 min.

Further modification of the Babcock method was reported by Salwin *et al.* (1955) using a perchloric acid-acetic acid mixture. The advantage of rapid analysis was retained as was the disadvantage of a small sample size. The method was reported to compare adequately with the AOAC method; however, Windham (1957) showed that the method gave approximately 5% higher fat values than the official method due to a retention of the extracting

acids. The work further substantiated the close agreement of both the Steinlite and modified Babcock methods with that of the AOAC. Using a patented flask, Wistreich *et al.* (1960) developed a solvent method using a 10 g sample and requiring approximately 3 hr per determination. Methods of specific gravity and templates have also been studied and possess some merit.

The reliability of an analytical procedure based on a patented thermal extraction apparatus, was investigated. The use of this thermal extraction method would: (1) eliminate a stock of chemical solvents and equipment; (2) reduce the sampling risk by the use of a 56.70 g (2 oz) sample, as opposed to a solvent extraction sample of 3 or 4 g; (3) reduce the time requirement of between 6 to 23 hr to 15 min; and (4) provide a portable kit which could be easily carried to the place of operation by Quality Control or Veterinary Corps inspectors. With the use of this unit, fat analyses could be facilitated by the reduction of time required for each analysis or additional determinations could be made in the same length of time currently required by conventional solvent extraction methods.

MATERIALS AND METHODS

U. S. GOOD TOP ROUNDS and commercially available trim fat were utilized in this study to prepare the ground beef samples. The top rounds and trim fat were analyzed for fat content, using the AOAC (1965) solvent method in order to determine the proportions of lean and fat required to fabricate ground meat with the desired fat percentages. Thermal fat analysis was conducted by the Hobart Manufacturing Co. method.

The portable apparatus, using as a thermal source for extraction an inverted hot plate suspended over the sample, requires approximately 15 min per determination. Using a doughnut-formed sample, this apparatus allows the rendered drippings, both meat juices and fat, to fall through a glass funnel into a glass tube. After the collection of the thermally extracted material, a base scale is adjusted to compensate for the volume of meat juices lying under the fat layer in the tube. The rendered fat column is then measured on a printed scale as percent fat.

The comparisons between the solvent and thermal extraction methods were made with ground beef samples of 16 fat levels, ranging between 14 and 29%. The proportions of lean meat and fat trim required for samples of each fat level were ground through a Buffalo Grinder (Model 41-B), using a plate having holes ¾-in. in diameter, followed by an additional grinding through a plate having holes ⅛-in. in diameter. Samples receiving this treatment are reported in this paper as "commercial ground" because

the treatment is similar to practices used in the commercial manufacture of ground beef.

After withdrawal of the "commercial ground" samples for both solvent and thermal fat extraction, the remaining portions were further processed by again grinding through a plate having holes ⅛-in. in diameter. These samples are known as "laboratory ground No. 2." "Laboratory ground No 3" samples were prepared by again repeating the ⅛-in. grinding operation on the final portion. The grinding process provided a continued reduction in meat particle size to promote the fat rendering as well as to improve the uniform distribution of fat and lean. Samples weighing approximately 8 oz were placed in 10 oz plastic containers and frozen at −10°F.

Solvent and thermal extractions were performed in triplicate on all samples for fat content. Sample size for all replications was 56.70 ± 0.01 g. Thermal extraction analyses are reported to the nearest 0.05% fat, this being the maximum precision to which the instruments scale could be read.

RESULTS AND DISCUSSION

RESULTS OF THE STUDY are presented in Table 1. The thermal extraction mean percentages do not show the continuous fat increase as does the solvent extraction means; however, the trend is definitely similar. The results indicate that as the amount of thermal sample grinding increased, the differences between the two methods also increased, with greatest differences occurring at approximately 20% fat. This continued fat loss through successive grinding was considered to be largely due to the adherence of fat to the internal surfaces of the grinder in spite of precautions to prevent its occurrence.

The solvent extraction method showed the smallest range of fat differences within replications while that of the thermal extraction method, being larger, decreased as the amount of grinding before extraction increased. The largest range between the two methods occurred at approximately 23% fat (AOAC method).

Both regression and correlation coefficients for all comparisons were significant at the 1% level, indicating a definite positive relationship (Table 2).

Replication point and regression line comparisons between solvent and the three thermal extraction samples, i.e., commercial ground samples, laboratory ground No. 2 samples, and laboratory ground No. 3 samples, are presented in Figs. 1a, 1b, and 1c, respectively.

Examination of the replication points about these regression lines suggests the possibility of a nonlinear relationship. A straight line applied to these data would, therefore, create some error in those areas of nonlinearity. These data were analyzed by a least-squares polynomial curve fit program (Tchebycheff polynomial method) through the fifth order. The variance and standard error for each polynomial order were calculated and these results are presented in Table 3.

For the three ground categories, both variance and standard error decreased as the polynomial increased

Table 1. Comparison of the means and ranges of fat percentages from solvents and thermal extraction analyses.

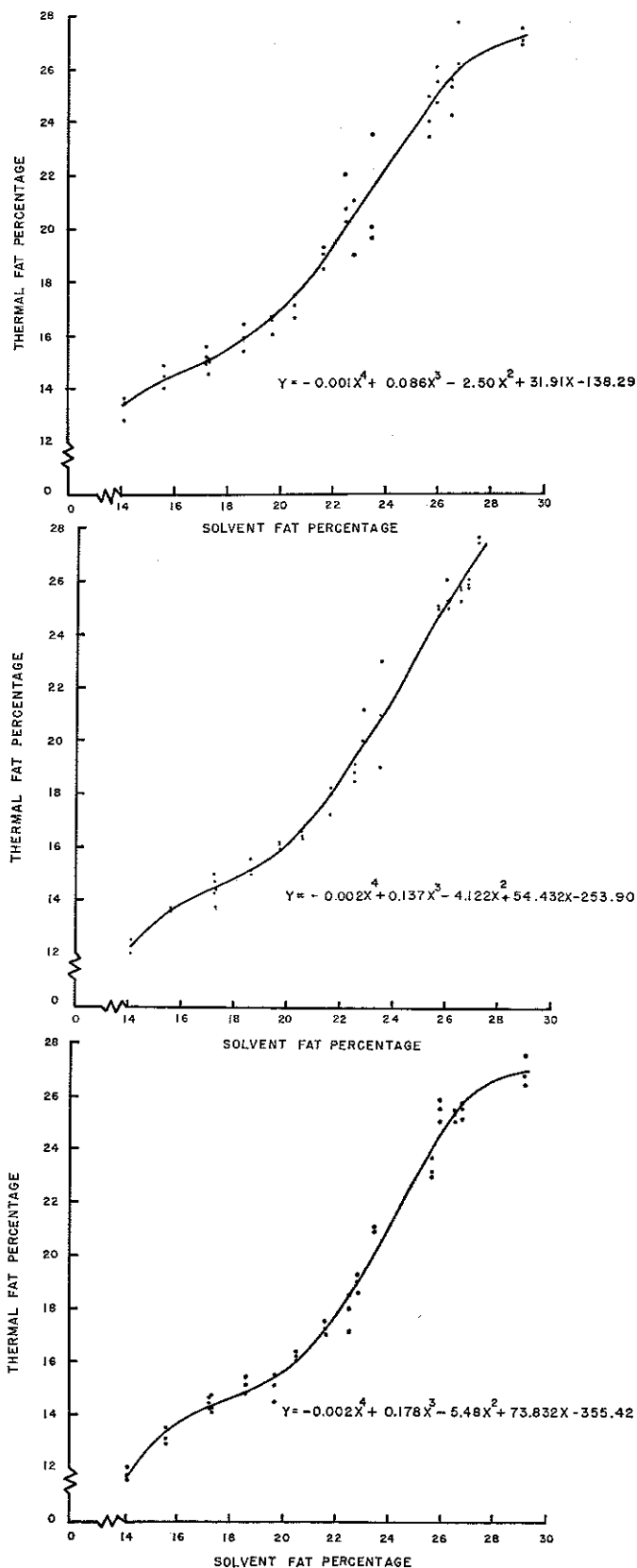| Solvent extraction analyses		Thermal extraction analyses					
Commercial ground		Commercial ground		Laboratory ground No. 2		Laboratory ground No. 3	
Mean	Range	Mean	Range	Mean	Range	Mean	Range
14.13	0.46	13.28	0.85	12.25	0.50	11.75	0.40
15.61	0.36	14.47	0.90	13.65	0.15	13.17	0.60
17.26	0.11	15.23	0.65	14.67	0.70	14.42	0.45
17.31	0.36	14.87	0.50	14.23	0.70	14.35	0.60
18.65	0.04	15.83	1.05	15.22	0.55	15.13	0.65
19.71	0.40	16.42	0.65	16.15	0.10	15.03	1.00
20.55	0.05	17.08	0.85	16.45	0.25	16.20	0.25
21.62	0.48	18.92	0.75	17.83	0.75	17.25	0.50
22.56	0.71	21.00	1.75	18.82	0.65	17.88	1.35
22.84	0.25	20.33	2.00	20.40	1.20	18.95	0.65
23.48	0.92	21.03	3.90	21.00	4.00	20.63	1.00
25.67	0.21	24.10	1.50	24.97	0.30	23.25	0.65
25.96	0.25	25.38	1.35	25.47	1.10	25.43	0.80
26.49	0.50	25.00	1.30	25.62	0.50	25.25	0.40
26.78	0.80	26.60	1.60	25.95	0.25	25.43	0.60
29.16	0.40	27.13	0.60	27.57	0.20	26.88	0.75
Average	0.39	....	1.26	....	0.74	....	0.67

Table 2. Regression and correlation coefficient between solvent and thermal extraction methods.

Chemical extraction	vs.	Thermal extraction	Regression coefficient	Correlation coefficient
"Commercial ground"		"Commercial ground"	1.045**	0.980**
"Commercial ground"		"Laboratory ground No. 2"	1.136**	0.978**
"Commercial ground"		"Laboratory ground No. 3"	1.104**	0.979**

** 1% level of significance.
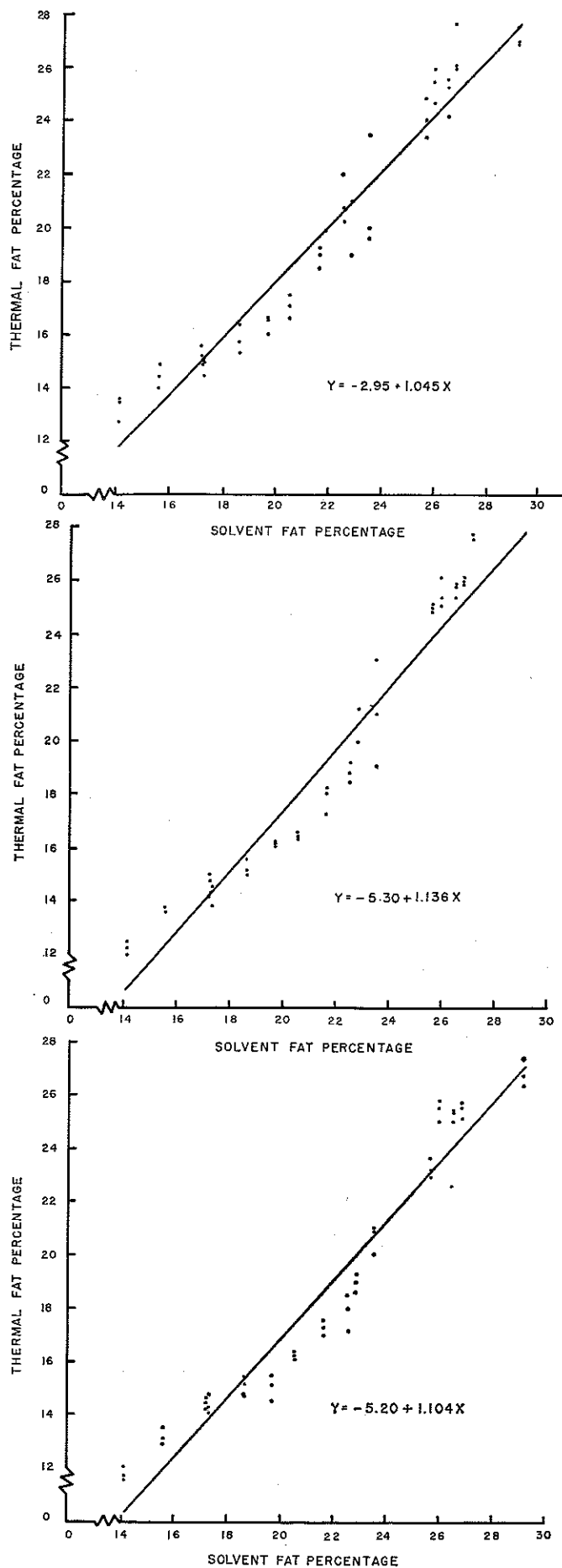
← *Fig. 1. Regression of solvent and thermal method of fat extraction. 1a—Commercial ground sample. 1b—Laboratory ground No. 2 sample. 1c—Laboratory ground No. 3 sample.*

$Y = -2.95 + 1.045 X$

$Y = -5.30 + 1.136 X$

$Y = -5.20 + 1.104 X$

$Y = -0.001X^4 + 0.086X^3 - 2.50X^2 + 31.91X - 138.29$

$Y = -0.002X^4 + 0.137X^3 - 4.122X^2 + 54.432X - 253.90$

$Y = -0.002X^4 + 0.178X^3 - 5.48X^2 + 73.832X - 355.42$

↑ *Fig. 2. Fourth order polynomial of solvent and thermal method of fat extraction. 2a—Commercial ground sample. 2b—Laboratory ground No. 2 sample. 2c—Laboratory ground No. 3 sample.*

Table 3. Variance and standard error between solvent and thermal extraction methods through the fifth polynomial.

	Commercial ground	Laboratory ground No. 2	Laboratory ground No. 3
First Order			
Variance	0.815	1.036	1.292
Standard error	0.965	1.088	1.215
Second Order			
Variance	0.541	0.599	0.760
Standard error	0.816	0.859	0.967
Third Order			
Variance	0.285	0.361	0.617
Standard error	0.617	0.694	0.907
Fourth Order			
Variance	0.170	0.085	0.167
Standard error	0.497	0.352	0.493
Fifth Order			
Variance	0.163	0.080	0.167
Standard error	0.511	0.358	0.517

through the fourth order, whereas in the fifth order this trend appears to reverse itself. The laboratory ground No. 2 variance and standard error values are lower than any of those representing the first three orders and are just as adequate as those of the fifth order. Thus, one additional $\frac{1}{8}$-in. grinding appears warranted, although further grinding provides no closer comparability than that of the commercial ground samples. Therefore, the fourth order polyynomial of the thermal extraction analysis, laboratory ground No. 2 samples, provides the closest estimate to the solvent extraction method.

For any given solvent extraction value (X), the comparable thermal extraction value (Y) may be computed from the following fourth order equation: $Y = 0.002X^4 + 0.137X^3 - 4.122X^2 + 54.432X - 253.90$. The fat replication values and the fourth order polynomial curves for commercial ground, laboratory ground No. 2, and laboratory ground No. 3 samples are shown in Figs. 2a, 2b, and 2c, respectively.

The mean thermal extraction values in Table 1 are smaller than those of their solvent extraction countervalues. The possibility of a fat residue remaining in the charred samples after thermal extraction may contribute to these differences; however, no investigation of possible remaining fat residue was undertaken. It should be further noted that smaller amounts of fat remained adsorbed to the surfaces of the collection apparatus, causing part of the further inaccuracy of the thermal method. This error is more significant in samples of lower fat content than those of high fat content.

The repeatability of the "cook-off" time, as measured by the thermal extraction unit's automatic timer, was measured to the nearest quarter minute. The time samples were exposed to the thermal extraction process ranging from $13\frac{1}{4}$ to $16\frac{3}{4}$ min; the mode being 14 min. A "cook-off" time in excess of 13 min is adequate for the thermal fat extraction.

CONCLUSION

THE THERMAL EXTRACTION METHOD is more rapid, yet provides results comparable to the solvent extraction method. The degree of comparability varied with the amount of sample preparation. Grinding samples once through a plate having $\frac{3}{4}$-in. diameter holes and twice through $\frac{1}{8}$-in. diameter holes provided the best combination of replication uniformity and accuracy.

On the basis of the results presented and discussed, it can be concluded that the thermal extraction method is rapid, reproducible, economical, and sufficiently accurate in the range of 14 to 29% fat. This method of fat extraction provides a valuable tool for use in food industry control procedures and for Armed Forces quality assurance tests.

This investigation did not demonstrate the economics of either method tested; however, the procedure of the thermal extraction method is obviously cheaper, requiring no solvents, no special sample preparation, nor a chemist.

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Ms. rec'd 12/23/66.